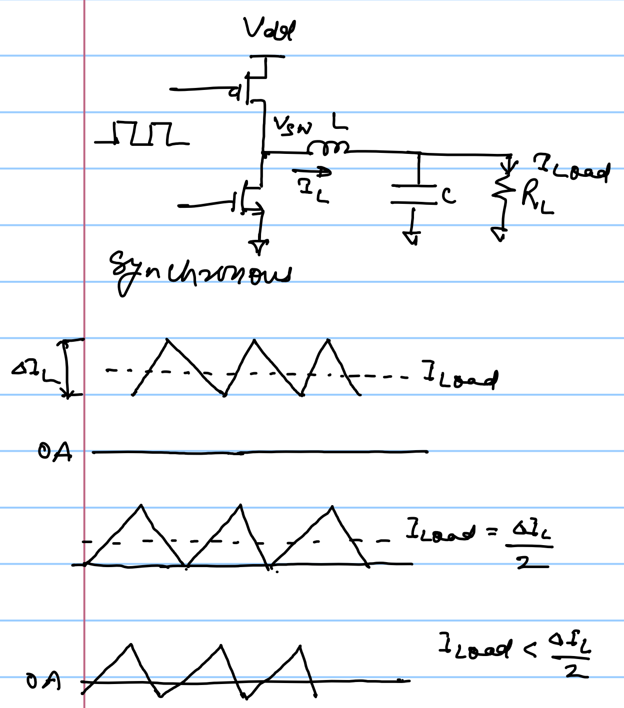
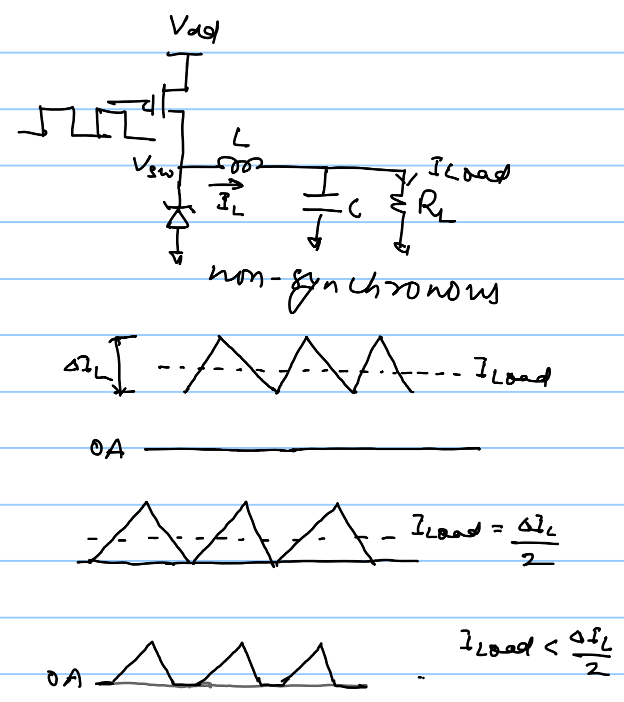
CCM vs. DCM operation

CCM → continuous conduction mode

DCM → dis-continuous conduction mode





	Synchronous	Nonsynchronous
1.	Allows reverse current so inductor is always conducting	Doesn't allow reverse current so inductor doesn't conduct if $I_{Load} < \frac{\Delta I_L}{2}$
2.	Losses are more due to reverse conduction.	Losses are reduced. → better efficiency
3.	works for all load currents (positive & negative)	works only for positive load currents $I_{Load} > 0$
4.	$V_o = D \cdot V_{dd}$ holds true	$V_o = D \cdot V_{dd}$ doesn't hold true.

CCM - DCM Boundary condition.

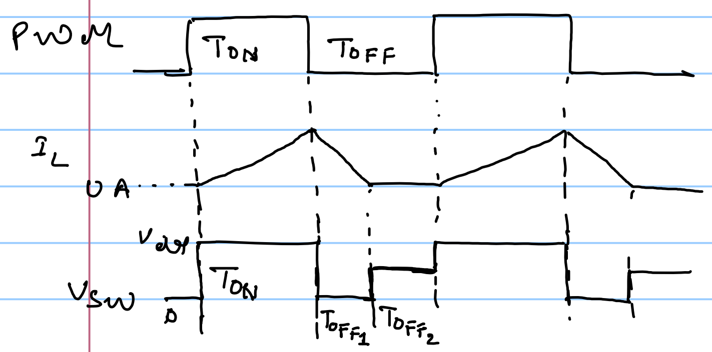
$$I_{Load} = \frac{\Delta i_L}{2} = \frac{1}{2}\frac{V_o}{L}(1-D)T_{sw}$$

$$1 - D = \frac{I_{Load}}{T_{sw}} \times \frac{L}{V_o}$$

$$I_{Load} = \frac{V_o}{R_L}$$

$$1 - D = \frac{2L}{R_L T_{sw}}$$

or $$D' = \frac{2L}{R_L T_{sw}} = k \text{ (critical factor)} \quad - (1)$$



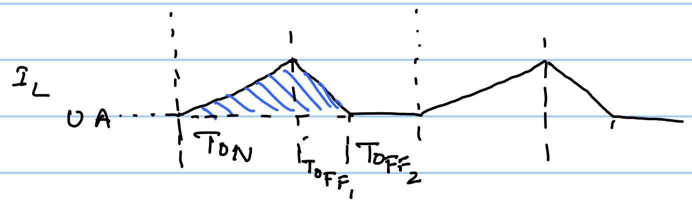
Average Voltage across inductor.

$$V_L(avg) = 0 = \frac{1}{T_{SW}}\left(\frac{V_{dd}-V_0}{L} \times T_{ON} + \frac{(-V_0)}{L} T_{OFF_1} + 0 \times T_{OFF_2}\right) = 0$$

$$\Rightarrow (V_{dd} - V_0)T_{ON} - V_0 T_{OFF_1} = 0$$

$$\Rightarrow T_{ON} + T_{OFF_1} = \frac{V_{dd}}{V_0} T_{ON} \quad \text{—— (2)}$$

$I_L(avg) = I_{Load}$



$$D' = \frac{2L}{R_L T_{SW}} = K$$

$$I_L(avg) = \frac{1}{2} \times (T_{ON} + T_{OFF_1}) \times \frac{V_{DD} - V_0}{L} \times T_{ON} = I_{Load}$$

from (2)

$$T_{ON} + T_{OFF_1} = \frac{V_{dd}}{V_0} \times T_{ON}$$

$$\left(\frac{1}{T_{SW}}\right) \frac{1}{2} \frac{V_{dd}}{V_0} T_{ON} \times \frac{\cancel{V_0}\left(\frac{V_{dd}}{V_0} - 1\right)}{L} \times T_{ON} = \frac{\cancel{V_0}}{R_L}$$

$$\frac{1}{\cancel{T_{SW}}} \times \frac{1}{2} \frac{V_{dd}}{V_0} (D \cdot \cancel{T_{SW}}) \left(\frac{V_{dd}}{V_0} - 1\right) \times D \cdot T_{SW}$$

$$\frac{V_{dd}}{V_0}\left(\frac{V_{dd}}{V_0} - 1\right) D^2 = \frac{2L}{R_L T_{SW}} = K$$

$$\left(\frac{V_{dc}}{V_o}\right)^2 - \frac{V_{dc}}{V_o} - \frac{K}{D^2} = 0$$

$$\frac{V_{dc}}{V_o} = x$$

$$ax^2 + bx + c$$

$$x = \frac{1 \pm \sqrt{1 + \frac{4K}{D^2}}}{2}$$

$$\frac{V_o}{V_{dc}} = \frac{2}{1 \pm \sqrt{1 + \frac{4K}{D^2}}}$$

for buck converter, $\frac{V_o}{V_{dc}} < 1$

$$\frac{V_o}{V_{dc}} \neq \frac{2}{1 - \sqrt{1 + \frac{4K}{D^2}}}$$

$$\frac{V_o}{V_{dd}} = \frac{2}{1+\sqrt{1+\frac{4K}{D^2}}}$$

$$D' = \frac{2L}{R_L T_{sw}} = K$$

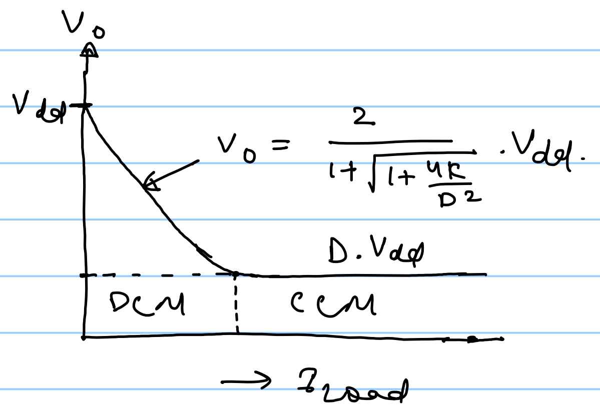
if $R_L \to \infty$

$K = 0$

$$\frac{V_o}{V_{dd}} = 1 \Rightarrow V_o = V_{in}$$

In CCM ; $V_o = D \cdot V_{dd}$

In DCM : $V_o = \dfrac{2}{1+\sqrt{1+\frac{4K}{D^2}}}$



For constant V_o & V_{in}

$$\frac{V_o}{V_{in}} = \frac{2}{1+\sqrt{1+\frac{4K}{D^2}}} = \text{constant}$$

$$\Rightarrow \frac{4K}{D^2} = \text{constant}$$

$$K = \frac{2L}{R_L \cdot T_{sw}}$$

$$\Rightarrow \frac{4}{D^2}\left(\frac{2L}{R_L T_{sw}}\right) = \text{constant}$$

$$\Rightarrow \frac{4}{D^2}\left(\frac{2L}{R_L T_{sw}}\right) = \text{constant}$$

for fixed L & T_{sw}

$R_L \uparrow \qquad D \downarrow$

For linear operation, we limit $T_{on} \rightarrow T_{on\_min}$

$$D = \frac{T_{ON}}{T_{sw}} = \frac{T_{ON\_min}}{T_{sw}} \quad \text{for high } R_L \text{ (lower } I_{Load}\text{)}$$

$$\frac{4}{T_{ON\_min}^2} \times T_{sw}^{\cancel{2}}\left(\frac{2L}{R_L \cancel{T_{sw}}}\right) = \text{constant}$$

$$\frac{8L}{T_{on\_min}^2}\left(\frac{T_{sw}}{R_L}\right) = \text{constant}$$

$\downarrow$

constant

$\frac{T_{sw}}{R_L}$ should be constant in order to regulate the output.

$R_L \uparrow$ $T_{sw} \uparrow$ or $F_{sw} \downarrow$

$F_{sw} \propto I_{Load}$.

Called PFM mode

Pulse Frequency Modulation